[54] Name of the invention

The present invention disclose a thermoelectric module that is constituted by a pair of substrates [1 and 2] having electrodes [11 and 12], which are arranged opposite to each other with a prescribed space therebetween, in which a prescribed number of thermoelectric elements [13] are arranged in such a way that a p-type and an n-type are alternately arranged, so that the thermoelectric elements are connected in series or in parallel together with the electrodes. Herein, one substrate is a heat absorption side, and other substrate is a heat radiation side. In addition, a current density in a current transmission area of the heat-absorption-side electrode is set to 50 A / mm$^2$ or less, and a height of the thermoelectric element is set to 0.7 mm or less. Furthermore, a temperature controlled semiconductor module can be realized by combining a thermoelectric module with a semiconductor component such as a semiconductor laser.

1. A thermoelectric module comprising:
a first substrate (2) for absorbing heat;
a plurality of first electrodes (12) arranged on a surface of the first substrate;
a second substrate (1) for radiating heat;
a plurality of second electrodes (11) arranged on a surface of the second substrate, which are arranged opposite to the first substrate; and
a plurality of thermoelectric elements (13), which are sandwiched between the plurality of first electrodes and the plurality of second electrodes, wherein the plurality of thermoelectric elements are of a p-type and an n-type that are arranged alternately, so that the thermoelectric elements are connected in series or in parallel together with the first electrodes and the second electrodes,
wherein a current density in a current transmission area of the first electrode is set to 50 A / mm$^2$ or less, and a height of the thermoelectric element is set to 0.7 mm or less.

2. A temperature-controlled semiconductor module comprising:
a semiconductor component; and
a thermoelectric module, which comprises
a first substrate (2) for absorbing heat,
a plurality of first electrodes (12) arranged on a surface of the first substrate,
a second substrate (1) for radiating heat,
a plurality of second electrodes (11) arranged on a surface of the second substrate, which are arranged opposite to the first substrate, and
a plurality of thermoelectric elements (13), which are sandwiched between the plurality of first electrodes and the plurality of second electrodes, wherein the plurality of thermoelectric elements are of a p-type and an n-type that are arranged alternately, so that the thermoelectric elements are connected in series or in parallel together with the first electrodes and the second electrodes,
wherein a current density of a current transmission area of the first electrode is set to 50 A / mm$^2$ or less, and a height of the thermoelectric element is set to 0.7 mm or less.

Thermoelectric Modules

Technical Field
The present invention relates to thermoelectric modules having endothermic properties
for absorbing heat from electronic components and the like.

Background Technology
        A conventional example of a thermoelectric module comprising an upper
substrate 2 and a lower substrate 1 will be described with reference to Figs. 6 to 9,
wherein Fig. 6 is a plane view showing the upper substrate 2, Fig. 7 is a right side view,
Fig. 8 is a front view, and Fig. 9 is a plane view showing the lower substrate 1. The upper
substrate 2 and the lower substrate 1, both of which are made of alumina, are arranged
opposite to each other with a prescribed space therebetween, in which upper electrodes 5
are arranged on the upper substrate 2, and lower electrodes 6 are arranged on the lower
substrate 1. The upper electrodes 5 and the lower electrodes 6 are alternately arranged to
sandwich different types of thermoelectric elements 3 therebetween. Specifically, p-type
thermoelectric elements and n-type thermoelectric elements are alternately arranged
between the upper electrodes 5 and the lower electrodes 6 except a leftmost lower
electrode 6a. A single n-type thermoelectric element is only arranged for the leftmost
lower electrode 6a, which is connected with a lead 7. In Figs. 6 to 9, symbols of arrows
show directions of currents flowing through the thermoelectric module. That is, a current
flows through the leftmost lower electrode 6a (see Fig. 8), from which the current flows
into the upper electrode 5 via the n-type thermoelectric element; and then, the current
flows into the lower electrode 6 adjoining the leftmost lower electrode 6a via the p-type
thermoelectric element. As described above, the current sequentially flows through the
lower electrode 6, n-type thermoelectric element 3, upper electrode 5, p-type
thermoelectric element 3, and lower electrode 6 in turn. Due to the Peltier effect, heat is
extracted from the upper substrate 2 and is then transferred to the lower electrode 1.
Therefore, an electronic component mounted on the surface of the upper substrate 2 is
cooled, so that heat is radiated from the lower substrate 1. Both the upper electrodes 5
and the lower electrodes 6 have the same thickness, which ranges from 50 μm to 100 μm,
for example.

        In the case of a thermoelectric module having a relatively large maximal
endothermic value Qcmax, a current flowing through electrodes may become large and
range from 5A to 10A, for example. This causes great heating values at electrodes, which
may deteriorate performance of the thermoelectric module.

        Incidentally, the maximal endothermic value Qcmax is defined with respect to a
thermoelectric module having a heat absorbing side and a heat radiating (or emitting) side,
wherein it is determined as an endothermic value that is produced when a difference
between temperature (Tc) of the heat absorbing side, on which a heater is mounted, and

temperature (Th) of the heat radiating side becomes zero (i.e., 0° C., where Tc = Th = 27 °C, for example).

Contents of the Invention

It is an object of the invention to provide a thermoelectric module that can be reduced in Joule heat even when a maximal endothermic value Qcmax is increased. In particular, it is an object of the invention to provide a thermoelectric module whose maximal endothermic value Qcmax is 12 W or more, in which Joule heat can be reduced.

A thermoelectric module of the present invention is constituted by a pair of substrates having electrodes, which are arranged opposite to each other with a prescribed space therebetween, in which a prescribed number of thermoelectric elements are arranged in such a way that a p-type and an n-type are alternately arranged, so that the thermoelectric elements are connected in series or in parallel together with the electrodes. Herein, one substrate is a heat absorption side, and the other substrate is a heat radiation side.

In the above, a current density in a current transmission area of the heat-absorption-side electrode is set to 50 A / mm$^2$ or less, and a height of the thermoelectric element is set to 0.7 mm or less.

In addition, a temperature controlled semiconductor module can be realized by combining a thermoelectric module with a semiconductor component such as a semiconductor laser. Herein, the thermoelectric module of the present invention can effectively reduce electric power consumption thereof particularly with respect to the semiconductor component having an endothermic value of 4 W or more.

Description of the Drawings

These and other objects, aspects, and embodiments of the present invention will be described in more detail with reference to the following drawings, in which:

Fig. 1 is a front view showing an essential structure of a thermoelectric module in accordance with a preferred embodiment of the invention;

Fig. 2 is a plane view of the thermoelectric module;

Fig. 3 is a graph showing a relationship between a current density of a current flowing through a prescribed electrode and a maximal value △Tmax of temperature difference between electrodes;

Fig. 4 is a graph showing a relationship between the height of a thermoelectric element and a maximal endothermic value Qmax;

Fig. 5 is a graph showing a relationship between the height of a thermoelectric element and a maximal value Imax of a current flowing through the thermoelectric element;

Fig. 6 is a plane view showing an upper substrate used in a conventional example of a thermoelectric module;

Fig. 7 is a right side view of the thermoelectric module;

Fig. 8 is a front view of the thermoelectric module;

Fig. 9 is a plane view showing a lower substrate of the thermoelectric module;

Fig. 10 diagrammatically shows the overall configuration of a thermoelectric module that is a sample produced for measurement;

Fig. 11 is a cross sectional view showing an example of a temperature-controlled semiconductor module that contains a semiconductor laser and a thermoelectric module; and

Fig. 12 is a graph showing relationships between electric power consumption and endothermic values, which are measured on samples of temperature-controlled semiconductor modules.

Specific Embodiments

The present invention will be described in further detail by way of examples with reference to the accompanying drawings.

Fig. 1 is a front view showing the essential structure of a thermoelectric module containing electrodes and thermoelectric elements in accordance with a preferred embodiment of the invention; and Fig. 2 is a plane view of the thermoelectric module. Herein, a pair of thermoelectric elements 13 consisting of an n-type and a p-type are arranged to adjoin together on a pair of lower electrodes 11 respectively, wherein they are both connected with an upper electrode 12. As similar to the conventional example of the thermoelectric module shown in Figs. 4 to 7, all the lower electrodes 11, upper electrode 12, and thermoelectric elements 13 are connected together, wherein the upper electrode 12 acts as a heat absorbing side (or a cooling side). Compared with the lower electrodes 11 that act as a heat radiating side, the upper electrode 12 acting as the heat absorbing side has a larger sectional area allowing transmission of a current therethrough (hereinafter, referred to as a current transmission area), which is determined in response to a drive current of the upper electrode 12 in such a way2that a current density thereof becomes equal to 50 A / mm or less. In addition, the thermoelectric element 13 has a prescribed height, which is equal to 0.7 mm or less, for example.

That is, the present embodiment is designed in such a way that the upper electrode 12 corresponding to the heat absorbing side is increased in current transmission area compared with the lower electrodes 11 corresponding to the heat radiating side, wherein the current density of the upper electrode 12 is set to 50 A / mm$^2$ or less, for example. Herein, a current density "i" representing a current flowing through the upper electrode 12, which corresponds to the heat absorbing side of the thermoelectric module, can be calculated by the following equation (see Figs. 1 and 2),

$$i = \frac{I}{W \cdot dl}$$

where dl denotes the thickness of the upper electrode 12, w denotes the width of the upper electrode 12, W denotes the width of the thermoelectric element 13, and I denotes a drive current.

Now, $\triangle$Tmax represents a maximal value of a temperature difference between the upper electrode 12 and the lower electrode(s) 11, which construct the thermoelectric module. We, the inventors, have examined relationships between the current density i and the maximal temperature difference $\triangle$Tmax representing performance of the thermoelectric module, wherein it is possible to provide a graph shown in Fig. 3, which shows that $\triangle$Tmax becomes extremely large (i.e., 100° C. or more) under the condition where the current density i is equal to 50 A / mm$^2$ or less. In particular, this effect is

closely related to the current density i measured in the upper electrode 12 corresponding to the heat absorbing side, wherein the performance of the thermoelectric module may be greatly reduced when the current density of the upper electrode 12 exceeds a prescribed value of 50 A / mm$^2$. For this reason, the present embodiment is designed in such a way that the current density i of a heat-absorbing-side electrode becomes 50 A / mm$^2$ or less when determining a current transmission area (W x dl) of the heat-absorbing-side electrode in response to a drive current. That is, the width W of the thermoelectric element 13 and the width dl of the electrode are determined to satisfy a prescribed inequality as follows:

$$\frac{I}{(W \times dl)} \leq 50 \quad \text{or}$$

$$W \times dl \geq \frac{I}{50}$$

Within parameters required for increasing the maximal endothermic value Qcmax in the thermoelectric module, we have particularly paid attention to the height of the thermoelectric element because of the following reasons.

The following three parameters are required for increasing the maximal endothermic value Qcmax.
(a) Sectional area of the thermoelectric element to be increased.
(b) Total sectional area of the thermoelectric element to be increased.
(c) Height of the thermoelectric element to be reduced.
Among these parameters, first and second parameters have prescribed limits in designs, which will be described below.
(a) In order to set a drive voltage of the thermoelectric module into a prescribed range between 2V and 3V, for example, the sectional area of the thermoelectric element may not be increased beyond a prescribed limit, which may range between 0.8 mm$^2$ and 1 mm$^2$.
(b) Because of the need to provide an insulation space between adjacent electrodes, even when a maximal number of thermoelectric elements are arranged in the thermoelectric module, the total sectional area of all the thermoelectric elements may not be increased beyond a prescribed percentage (e.g., 60% or so) compared with the total substrate area.
As described above, it is necessary to reduce the height of the thermoelectric element in order to increase the maximal endothermic value Qcmax of the thermoelectric module. The aforementioned graph of Fig. 5 shows that as the height of the thermoelectric element decreases, it is possible to increase a maximal value Imax of a current flowing through the thermoelectric element. Thus, it is realized from a graph of Fig. 4 that Qcmax becomes equal to 12W or more when the height of the thermoelectric element is equal to 0.7 mm or less.

As described above, the maximal endothermic value Qcmax of the thermoelectric module can be increased as the height of the thermoelectric element 13 decreases, so that it is possible to increase a cooling efficiency of the thermoelectric module. In order to obtain a satisfactory cooling effect, it is necessary to reduce the height of the thermoelectric element 13 to be equal to 0.7 mm or less. Fig. 4 is a curve graph in which

a horizontal axis represents the height of the thermoelectric element 13, and a vertical axis represents Qcmax, which is measured in units of watts (W). Fig. 4 shows that Qcmax becomes equal to approximately 12W or more under the condition where the height of the thermoelectric element 13 is 0.7 mm or less. Fig. 5 is a graph in which a horizontal axis represents the height of the thermoelectric element, and a vertical axis represents a maximal value Imax of a current flowing through the thermoelectric element 13, wherein Imax is measured in units of amperes (A). Fig. 5 shows that Imax becomes extremely high to be approximately 6 A or more under the condition where the height of the thermoelectric element 13 is 0.7 mm or less.

Fig. 10 shows a sample of a thermoelectric module that is actually produced in conformity with the following dimensions.

Substrate size: 8 mm x 12 mm

Size of thermoelectric element: 1 mm x 0.8 mm x 0.7 mm (height)

Electrode size: 1 mm (w) x 0.1 mm (dl)

Total sectional area of thermoelectric elements: 57 $mm^2$

Measurement results of the aforementioned sample of the thermoelectric module are as follows:
Imax: 5A
i: 50A/$mm^2$
Qcmax: 12W
△Tmax: 100°C.

The present invention may be applied to a temperature-controlled semiconductor module (see Fig. 11) in which a thermoelectric module is combined together with a semiconductor laser and the like for use in optical communications, for example. Herein, 113 designates a semiconductor laser, 114 designates a heatsink, 115 designates a header, 116 designates a light receiving element, 117 designates a lens, 118 designates a lens holder, 119 designates a base, 120 designates an insulation plate, 121 designates a board, 122 designates a side wall, 123 designates Peltier elements, 124 designates a light pickup window, 125 designates a lens, 126 designates an optical fiber, and 127 designates a sleeve.

Samples of temperature-controlled semiconductor modules each containing a semiconductor laser (or an excitation laser) and a thermoelectric module are produced by controlling current transmission areas of electrodes in thermoelectric modules, wherein one sample realizes a current density of 50A/$mm^2$ (Imax), and the other sample realizes a current density of 100A/$mm^2$ (Imax), for example. Herein, electric power consumption is measured with respect to thermoelectric modules having various endothermic values on which semiconductor lasers are mounted. Measurement results are shown in Fig. 12, wherein a horizontal axis represents endothermic values for semiconductor lasers, and a

vertical axis represents electric power consumption of thermoelectric modules. As endothermic values for semiconductor devices become large, electric power consumption of thermoelectric modules is correspondingly increased, so that currents flowing through thermoelectric modules are increased. This indicates that electric power consumption decreases in thermoelectric modules whose electrodes are relatively thick (or whose current transmission areas are relatively large) and whose current densities are relatively small. In particular, the present invention may effectively work in reduction of electric power consumption with respect to semiconductor lasers having endothermic values of 4 W or more.

As described heretofore, the present invention has a variety of effects and technical features, which will be described below.

(1) The present invention is designed in such a way that in a thermoelectric module constituted by thermoelectric elements sandwiched between electrodes, a current density of a heat-absorbing-side electrode (e.g., an upper electrode) is set to 50 A / $mm^2$ or less, while the height of the thermoelectric element is set to 0.7 mm or less. Thus, it is possible to reliably prevent performance of the thermoelectric module from being reduced due to Joule heating.

(2) Specifically, a thermoelectric module of the present invention is constituted by thermoelectric elements of p-types and n-types that are alternately arranged between upper electrodes and lower electrodes, wherein a current density of a current transmission area of the upper electrode(s) corresponding to the heat absorbing side is set to 50 A / $mm^2$ or less, while the height of the thermoelectric element is set to 0.7 mm or less.

(3) In addition, the present invention can be applied to temperature-controlled semiconductor modules each containing a semiconductor laser and a thermoelectric module, wherein it is possible to noticeably reduce electric power consumption of the thermoelectric module in a prescribed range of endothermic values for the semiconductor laser.

As the present invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive, since the scope of the invention is defined by the appended claims rather than by the description preceding them, and all changes that fall within metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the claims.
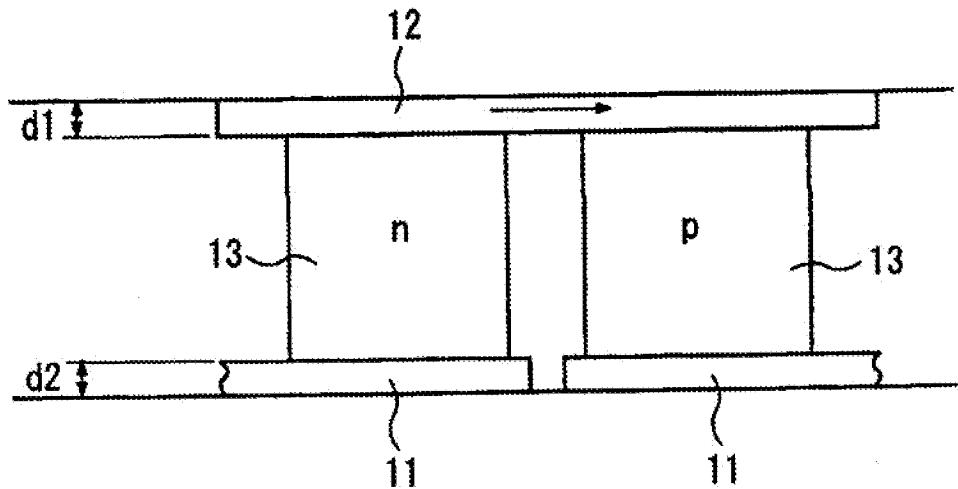
Fig. 1
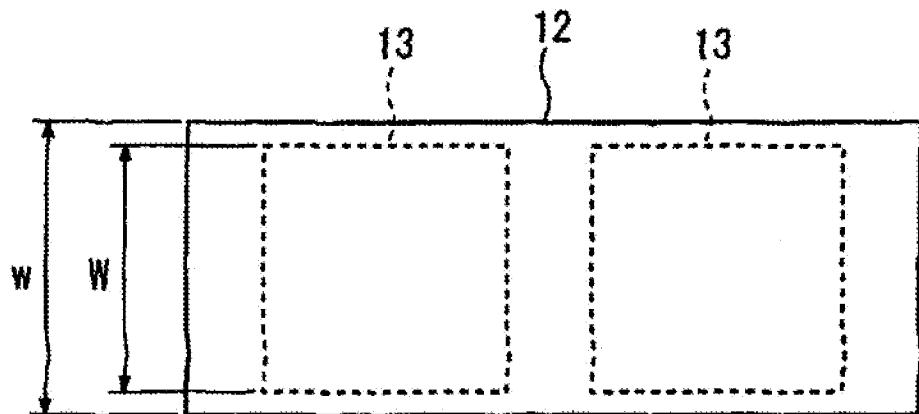
Fig. 2

The relationship between the current density and $\triangle$Tmax



Current density (A /mm$^2$)
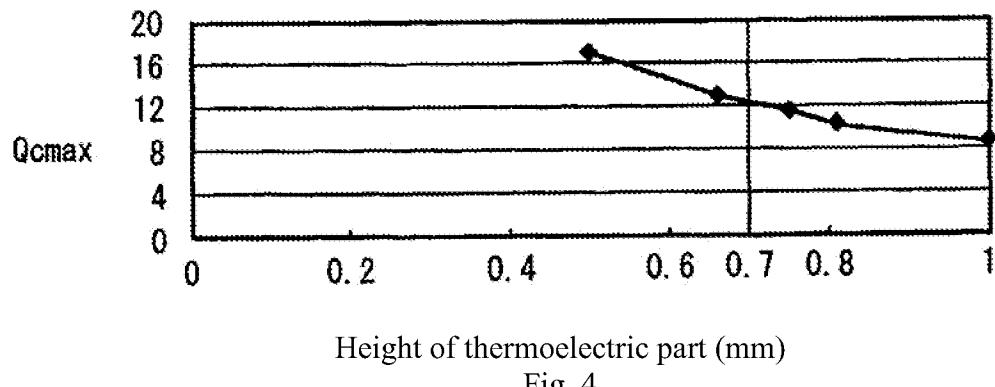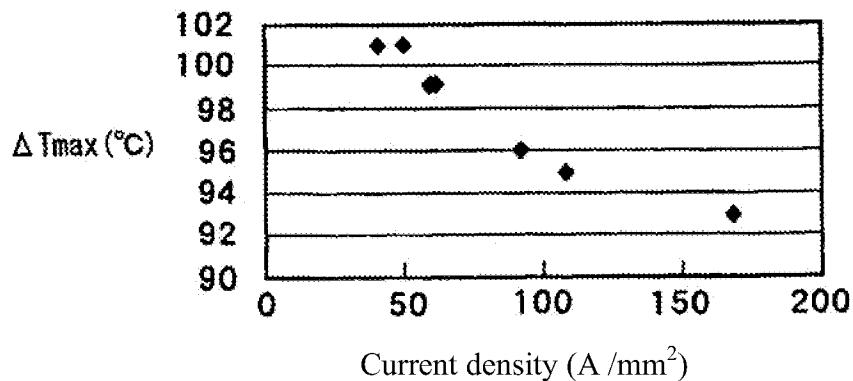


Height of thermoelectric part (mm)

Fig. 4
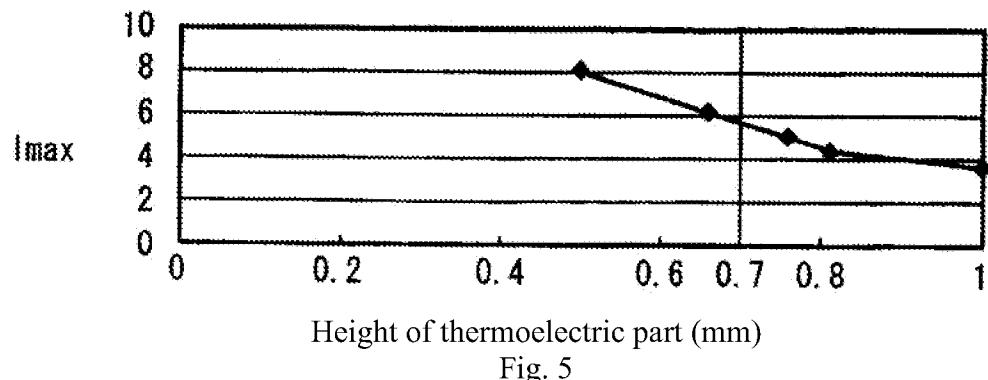
Height of thermoelectric part (mm)
Fig. 5



Fig. 6

Fig. 7



Fig. 8

Fig. 9

Electrode
thickness
0.1 mm

1. 0mm

0. 7mm

0. 8mm

12mm

8mm
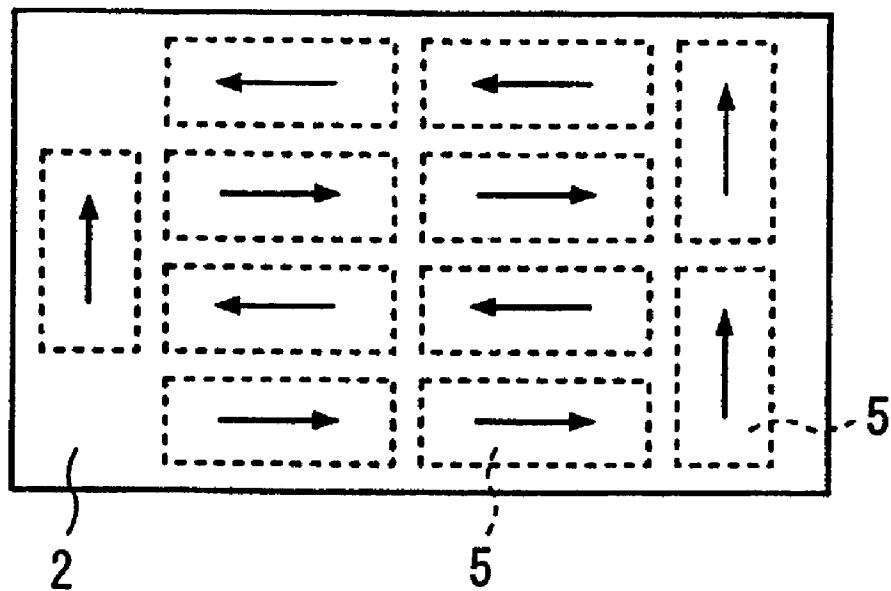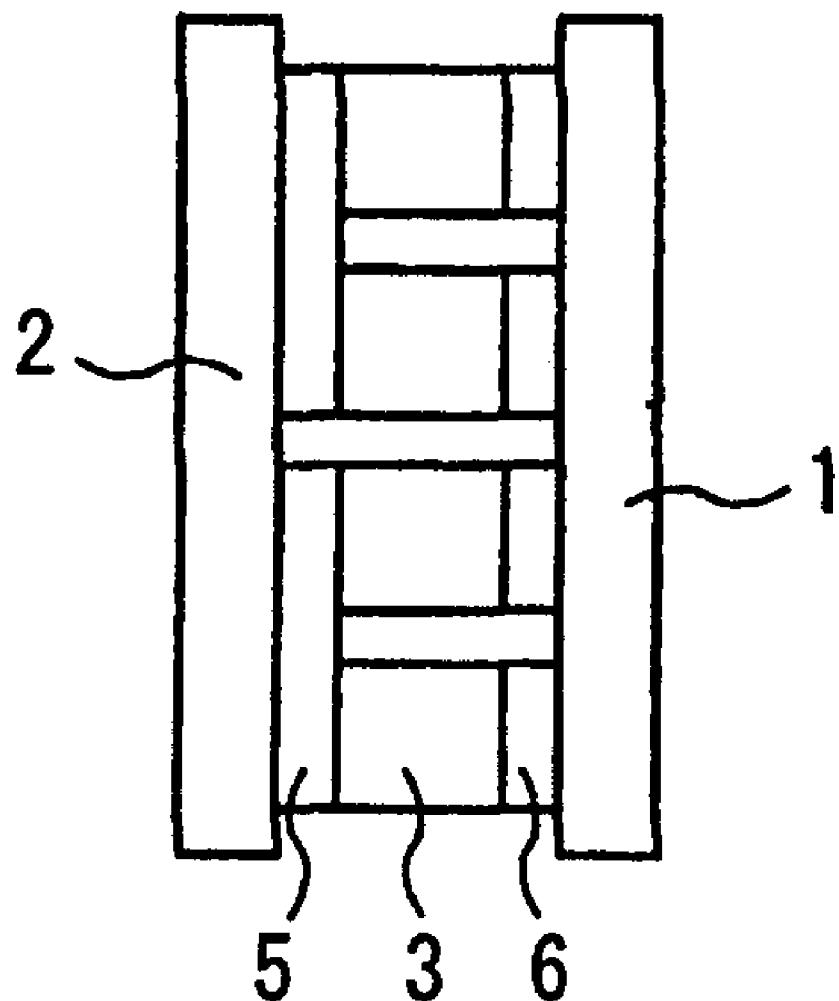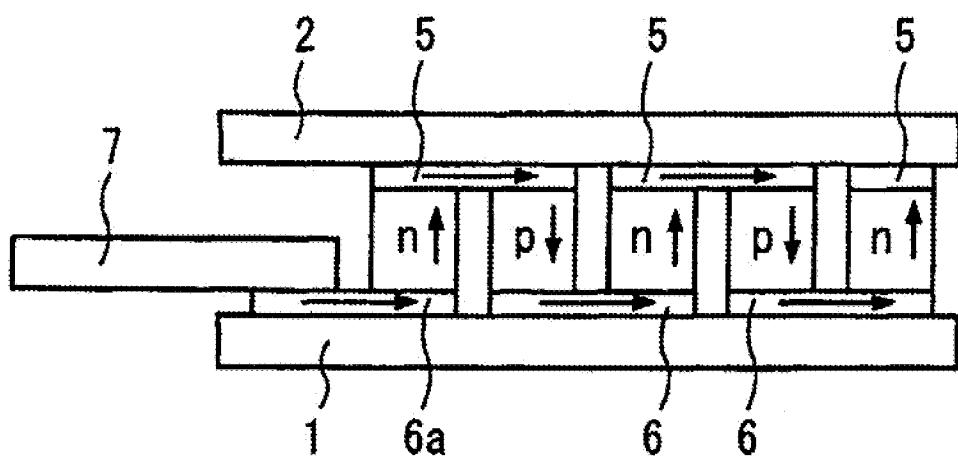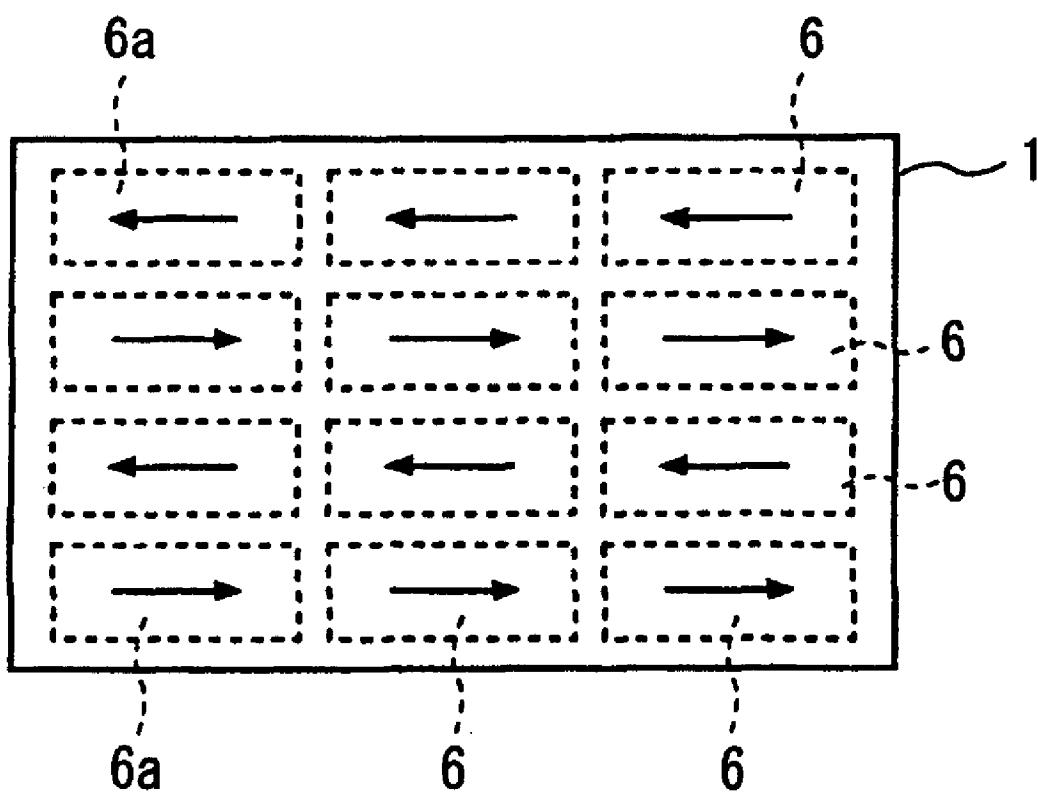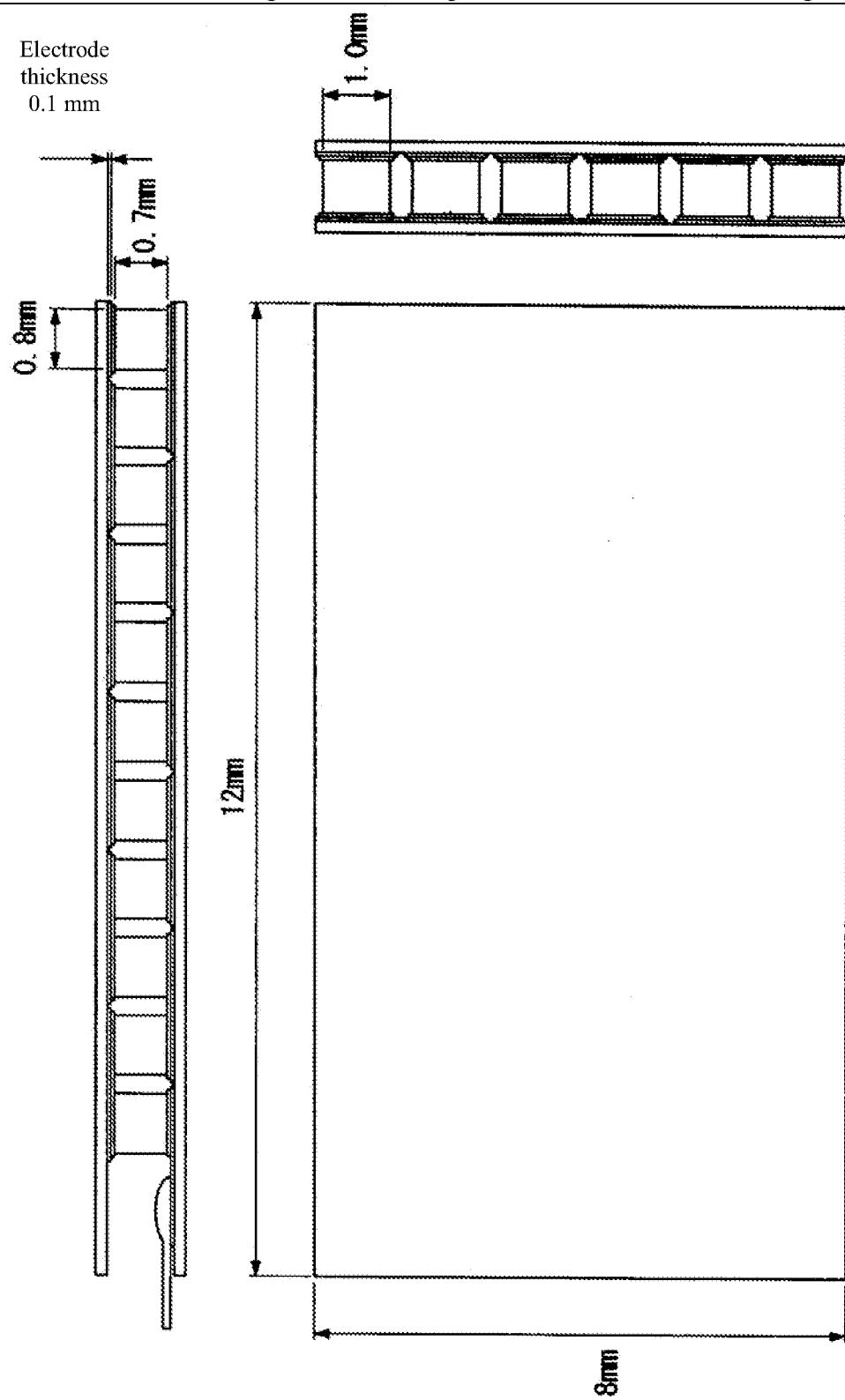
Fig. 10
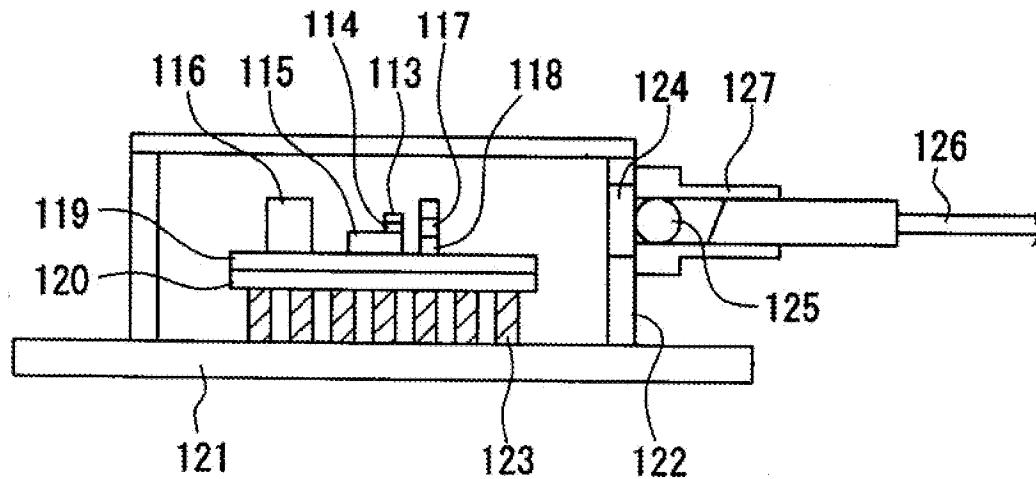
Fig. 11

Effect of current density in excitation laser module
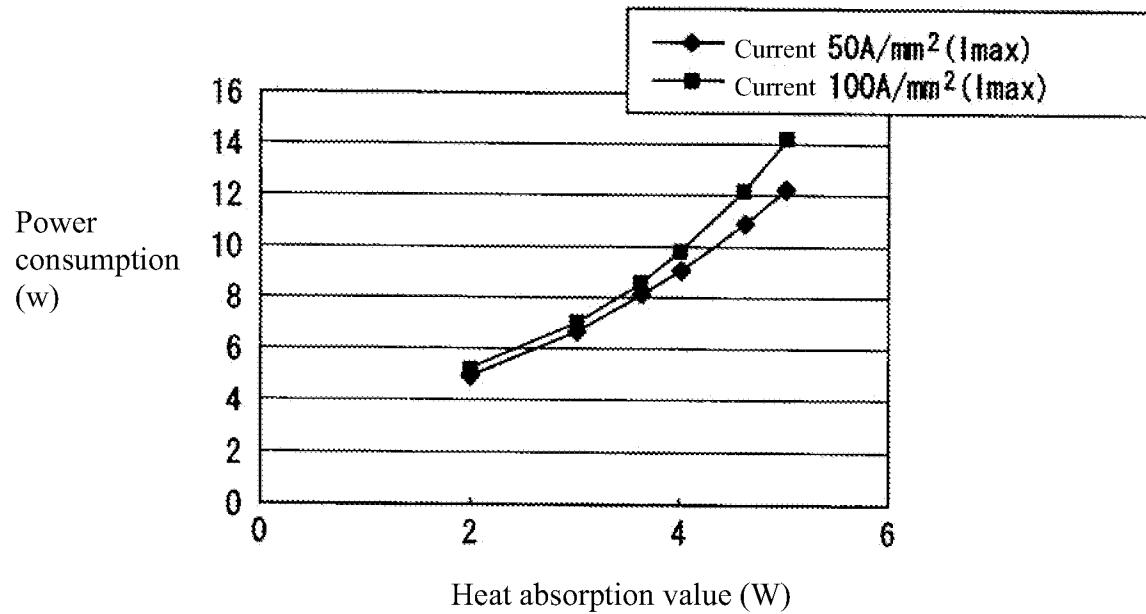


Fig. 12

[54] 发明名称　热电模块

[57] 摘要

　　本发明公开了一种热电模块，该热电模块由一对具有电极(11，12)的基片(1，2)构成，此对基片彼此相对地设置，其间具有规定的距离，规定数目的热电部件(13)以这样一种方式置于其中，即，p型和 n 型交替地排列，从而使热电部件串联地或并联地与电极连接在一起。 这里，一个基片是吸热侧，另一个基片是散热侧。 此外，在吸热侧电极的电流传输区中的电流密度设定为 50A/mm² 或更小，热电部件的高度设定为 0.7mm 或更小。 进而，通过组合热电模块与一个半导体部件例如半导体激光器，可以实现一个温度控制的半导体模块。
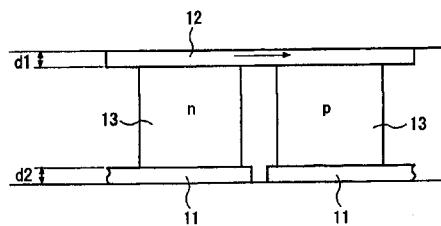
1. 一种热电模块，包括:

用于吸热的第一基片(2);

置于第一基片表面上的多个第一电极(12);

用于散热的第二基片(1);

置于第二基片表面上的多个第二电极(11)，其与第一基片相对；和

多个热电部件(13)，其夹在多个第一电极和多个第二电极之间，其中多个热电部件是交替排列的 p 型和 n 型部件，因此热电部件与第一电极和第二电极串联或并联连接在一起，

其中，第一电极的电流传输区的电流密度设定为等于或小于 50A/mm$^2$，并且热电部件的高度设定为等于或小于 0.7mm。

2. 一种温控半导体模块，包括:

一个半导体部件；和

一个热电模块，该热电模块包括:

用于吸热的第一基片(2)，

置于第一基片表面上的多个第一电极(12)，

用于散热的第二基片(1)，

置于第二基片表面上的多个第二电极(11)，其与第一基片相对，和

多个热电部件(13)，其夹在多个第一电极和多个第二电极之间，其中多个热电部件是交替排列的 p 型和 n 型部件，因此热电部件与第一电极和第二电极串联或并联连接在一起，

其中，第一电极的电流传输区的电流密度设定为等于或小于 50A/mm$^2$，并且热电部件的高度设定为等于或小于 0.7mm。

<center>热电模块</center>

5　　　　技术领域

本发明涉及具有吸热性质的热电模块,用于从电子部件等吸收热量。

技术背景

下面参照附图6-9描述其中包括上基片2和下基片1的常规热电模块的
10　例子,其中图6是表示上基片2的平面图,图7是右侧视图,图8是前视
图,图9是表示下基片1的平面图。上基片2和下基片1两者都是由氧化
铝制成的,它们彼此相对地设置,其间具有规定的距离,其中的上电极5
设在上基片2上,下电极6设在下基片1上。上电极5和下电极6交替地
设置,以便在它们之间夹持不同类型的热电部件3。特别地,除了最左边
15　的下电极6a以外,在上电极5和下电极6之间交替地设置p型热电部件和
n型热电部件。对于与引线7相连的最左边的下电极6a,只设置一个n型热
电部件。在图6-9中,箭头符号表示流过热电模块的电流的方向。即,电流
流过最左边的下电极6a(见图8),从这里电流经过n型热电部件流入上电极
5;然后,电流经过p型热电部件流入靠近最左边的下电极6a的下电极6。
20　如以上所述,电流依次流过下电极6、n型热电部件3、上电极5、p型热电
部件3、和下电极6。由于珀尔帖效应,从上基片2提取热量,然后把热量
传送到下基片1。因此,使装在上基片2的表面上的电子部件冷却,从而可
以使热量从下基片1辐射出来。上电极5和下电极6这两者都有相同的厚
度,其厚度范围例如从50微米到100微米。

25　　　　在具有相当大的最大吸热值Qcmax的热电模块的情况下,流过电极的
电流可以变得很大,例如范围从5A到10A。这在电极处产生巨大的热量,
可能使热电模块的性能变坏。

顺便说一下,最大吸热值Qcmax是针对具有吸热侧和放热(或者发热)
侧的热电模块确定的,其中最大吸热值Qcmax确定为在吸热侧(加热器置于
30　其上)的温度(Tc)和放热侧的温度(Th)之间的差变为0时(0°C,例如这时
Tc=Th = 27℃)产生的吸热值。

<center>3</center>

发明内容

本发明的一个任务是提供一种热电模块，这种热电模块即使在最大吸热值 $Qcmax$ 增加时也能使焦耳热减小。更详细地说，本发明的任务是提供最大吸热值为12W或更大的热电模块，其中焦耳热能够得以减小。

本发明的热电模块由一对具有电极的基片构成，这对基片彼此相对地设置，其间具有规定的距离，规定数目的热电部件(13)以这样一种方式置于其中，即，p型和n型交替地排列，从而使热电部件串联地或并联地与电极连接在一起。这里，一个基片是吸热侧，另一个基片是散热侧。

如以上所述，在吸热侧电极的电流传输区中的电流密度设定为 $50A/mm^2$ 或更小，热电部件的高度设定为0.7mm或更小。

此外，通过组合热电模块与一个半导体部件例如半导体激光器，可以实现一个温度控制的半导体模块。这里，本发明的热电模块可以有效地减小它的电力消耗，尤其是对于具有4瓦或以上的吸热值的半导体部件更是如此。

附图说明

参照以下的附图更加详细地说明本发明的这些和其它任务、方面和实施例。

图1是一个前视图，其示出了根据本发明的一个优选实施例的热电模块的主要结构；

图2是该热电模块的一个平面图；

图3是一个曲线图，其示出了流过规定电极的电流的电流密度与在电极之间的温度差的最大值 $\Delta Tmax$ 之间的关系；

图4是一个曲线图，其示出了热电部件的高度和最大吸热值 $Qmax$ 之间的关系；

图5是一个曲线图，其示出了热电部件的高度和流过热电部件的电流的最大值 $Imax$ 之间的关系；

图6是一个平面图，其示出了用在常规的热电模块实例中的一个上基片；

图7是热电模块的右侧视图；

图 8 是热电模块的前视图；

图 9 是一个平面图，其示出了热电模块的下基片；

图 10 示意地表示一个热电模块的总体结构，它是为测量生产的一个样品；

图 11 是一个剖面图，其示出了包括半导体激光器和热电模块在内的一个温控半导体模块的一个实例；

图 12 是一个曲线图，其示出了电力消耗和吸热值之间的关系，吸热值是在温控半导体模块的样品上测量的。

**具体实施方式**

下面参照附图借助于实例更加详细描述本发明。

图 1 是一个前视图，其示出了根据本发明的一个优选实施例的包括电极和热电部件的热电模块的主要结构，图 2 是这个热电模块的平面图。这里，包括 n 型和 p 型的一对热电部件 13 分别置于一对下基片 11 上以彼此靠近，其中该对热电部件都与上电极 12 连接。与如图 4-7 所示的常规的热电模块的实例类似，下电极 11、上电极 12 和热电部件 13 全都连接在一起，其中上电极 12 用作吸热侧(或者冷却侧)。与用作放热侧的下电极 11 相比，用作吸热侧的上电极 12 具有较大的截面积，允许通过此处的电流的传输(下面，称之为电流传输区)，这个截面积是根据上电极 12 的驱动电流确定的，以使电流密度等于 50A/mm$^2$ 或更小。此外，热电部件 13 具有一个规定的高度，这个高度例如等于 0.7mm 或更小。

即，按照以下所述的方式设计本实施例：与对应于放热侧的下电极 11 相比，对应于吸热侧的上电极 12 在电流传输区是增加的，其中上电极 12 的电流密度例如设定为 50A/mm$^2$ 或更小。这里，可以通过下述公式（见图 1 和 2）计算代表流过上电极 12 的电流的电流密度 "i"，所说的上电极 12 对应于热电模块的吸热侧。

$$i = \frac{I}{W \cdot d1}$$

这里，d1 代表上电极 12 的厚度，w 代表上电极 12 的宽度，W 代表热电部件 13 的宽度，I 代表驱动电流。

现在，△Tmax 代表在构成热电模块的上电极 12 和下电极(一个或多

个)11 之间的温差的最大值。发明人已经考察了电流密度 i 和代表热电模块的性能的最大温差 △Tmax 之间关系，其中有可能提供如图 3 所示的曲线，这个曲线表明：△Tmax 在电流密度 i 等于或小于 50A/mm² 的条件下变为极大值(即，100°C 或更大)。具体来说，这一效果与在对应于吸热侧的上电极 12 中测得的电流密度 i 紧密相关，其中当上电极 12 的电流密度超过了 50A/mm² 的规定值的时候，热电模块的性能大大地降低。出于这个理由，对于本实施例进行设计，使得在确定吸热侧电极的电流传输区(W × d1)以响应驱动电流时吸热侧电极的电流密度 i 等于或小于 50A/mm²。即，确定热电部件 13 的宽度 W 和电极的厚度 d1 来满足规定的如下不等式：

$$\frac{I}{(W \times d1)} \leq 50 \quad \text{或者}$$

$$W \times d1 \geq \frac{I}{50}$$

在为了增加热电模块中的最大吸热值 Qcmax 所需的参数中，出于下述理由我们特别关注热电部件的高度。

为了增加最大吸热值需要以下三个参数：

(a)热电部件要增加的截面积。

(b)热电部件要增加的总截面积。

(c)热电部件要减小的高度。

在这些参数当中，第一和第二个参数在设计中有规定的限值，下面对此进行描述。

(a)为了将热电模块的驱动电压设定在例如 2V 和 3V 之间的规定范围内，可以不增加热电部件的截面积使其超过规定的限值，规定的限值范围在 0.8mm² 和 1mm² 之间。

(b)因为在相邻的电极之间需要提供一个绝缘空间，即使当最大数目的热电部件置于热电模块中时，所有的热电部件的总截面积不得增加到超过总基片面积的一个规定的百分数(例如，60%左右)。

如以上所述，为了增加热电模块的最大吸热值 Qcmax，必须减小热电部件的高度。上述的图 5 的曲线表明：当热电部件的高度减小时，有可能增加流过热电部件的电流的最大值 I max。因此，从图 4 的曲线可以看出，当热电部件的高度等于或小于 0.7mm 时，Qcmax 变为等于或大于 12W。

如以上所述，热电模块的最大吸热值 Qcmax 可以随着热电部件 13 的高度的减小而增加，从而有可能增加热电模块的冷却效率。为了获得满意的冷却效率，必须减小热电部件 13 的高度使其等于或小于 0.7mm。图 4 是一个曲线图，其中的水平轴代表热电部件 13 的高度，垂直轴代表 Qcmax，Qcmax 的测量单位是瓦特(W)。图 4 表明：在热电部件 13 的高度等于或小于 0.7mm 的条件下，Qcmax 大约等于或大于 12W。图 5 是一个曲线图，其中的水平轴代表热电部件的高度，垂直轴代表流过热电部件 13 的电流的最大值 Imax，其中 Imax 的测量单位是安培(A)。图 5 表示：在热电部件 13 的高度等于或小于 0.7mm 的条件下，Imax 变为极大，等于或大于 6A。

图 10 表示热电模块的一个样品，它是按照下述的尺寸实际生产出来的。

基片大小：8mm×12mm

热电部件的大小：1mm×0.8mm×0.7mm(高度)

电极大小：1mm(w)×0.1mm(d1)

热电部件的总截面积：57mm$^2$

上述的热电模块的样品的测量结果如下：

Imax：5A

i：50A/mm$^2$

Qcmax：12W

△Tmax：100℃

本发明可以应用到温控半导体模块(见图 11)中，其中一个热电模块与一个半导体激光器等组合在一起，例如用于光通信中。这里，113 代表半导体激光器，114 代表散热器，115 代表底座(header)，116 代表一个受光元件，117 代表透镜，118 代表透镜架，119 代表基座，120 代表绝缘板，121 代表一个底板，122 代表侧壁，123 代表珀尔帖元件，124 代表光拾取窗口，125 代表透镜，126 代表光纤，127 代表一个套筒。

通过在热电模块中控制电极的电流传输区，产生出每个均包括半导体激光器(或者激发激光器)和热电模块在内的温控半导体模块样品，例如其中的一个样品获得的电流密度(Imax)为 50A/mm$^2$，另一个样品获得的电流密度(Imax)为 100A/mm$^2$。这里，针对装有半导体激光器的具有各种吸热值的热

电模块测量电力消耗。在图 12 中表示出测量结果，其中水平轴代表半导体激光器的吸热值，垂直轴代表热电模块的电力消耗。当半导体设备的吸热值变大时，热电模块的电力消耗也相应地增加，从而使流过热电模块的电流增加。这表明：在其电极相对厚(或其电流传输区相对大)并且其电流密度

5　相对小的热电模块中的电力消耗减小。具体来说，对于吸热值等于或大于 4W 的半导体激光器，本发明在减小电力消耗方面的效果很好。

　　　　如以上所述，本发明具有许多效果和技术特征，如以下所述。

　　　　(1)对于本发明进行设计，以便在由夹在电极之间的热电部件构成的热电模块中将吸热侧电极(例如上电极)的电流密度设置在等于或小于

10　$50A/mm^2$，同时将热电部件的高度设定为等于或小于 0.7mm。于是，有可能可靠地防止热电模块的性能因为存在焦耳热而下降。

　　　　(2)具体来说，本发明的热电模块由在上电极和下电极之间交替排列的 p 型和 n 型热电部件构成，其中对应于吸热侧的上电极(一个或多个)的电流传输区的电流密度设定为等于或小于 $50A/mm^2$，而热电部件的高度设定为等

15　于或小于 0.7mm。

　　　　(3)此外，本发明可以应用到温控半导体模块上，每个温控半导体模块包含一个半导体激光器和一个热电模块，其中在半导体激光器的吸热值的规定范围内，有可能显著减小热电模块的电力消耗。

　　　　因为本发明可以有几种方式实施而不偏离本发明的精神或本质特征，

20　所以本实施例是说明性的而不是限制性的，本发明的范围仅由所附的权利要求书确定而不由上述的描述确定，本发明范围内的所有的变化均限定在权利要求书的范围内。

图 1

图　2

电流密度和 △Tmax 之间的关系



电流密度(A/mm²)

图　3
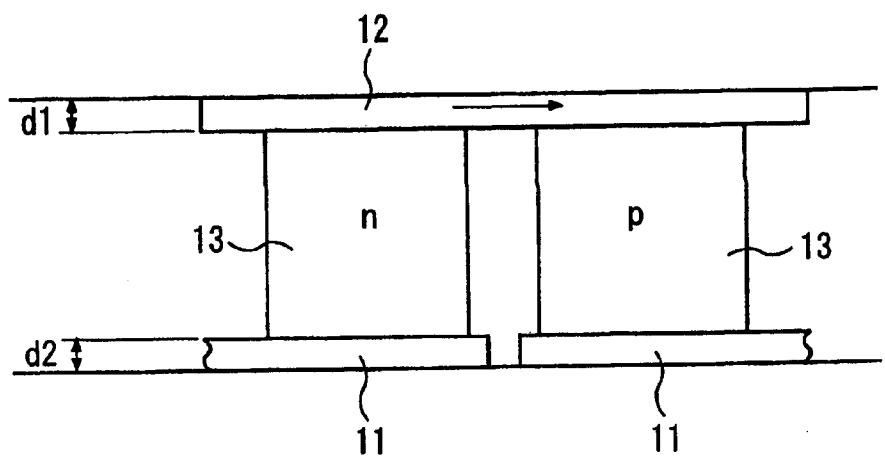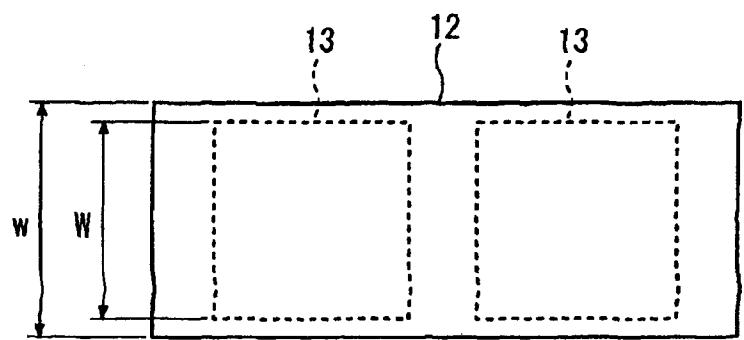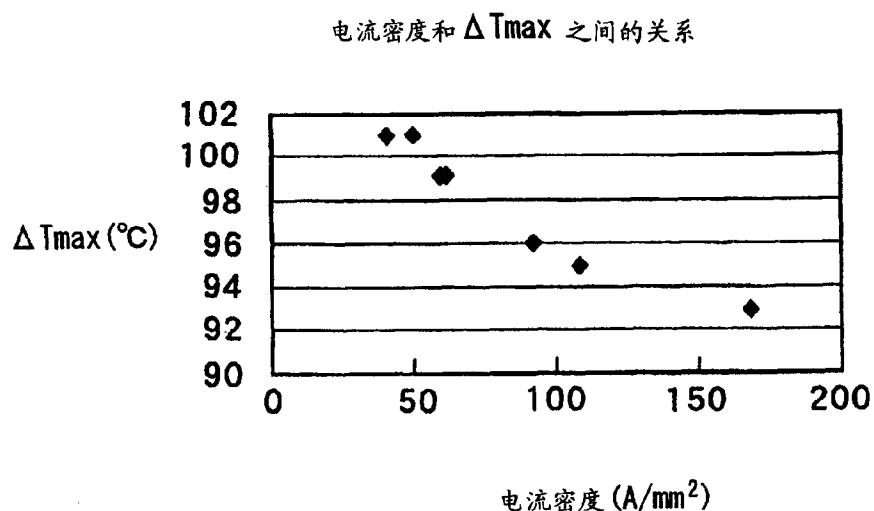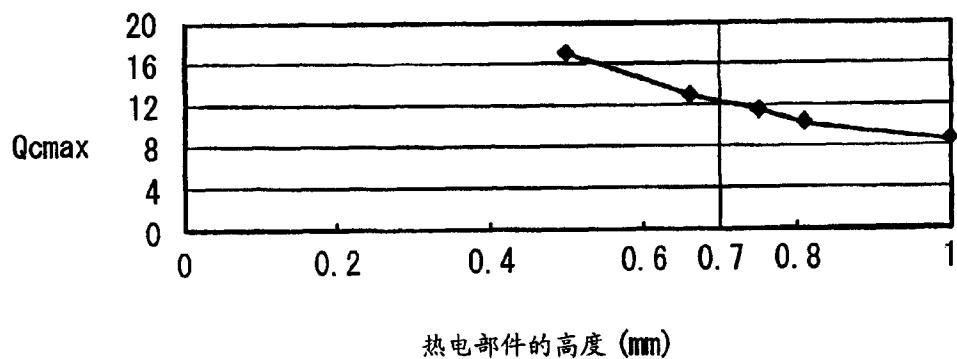


热电部件的高度(mm)

图　4

热电部件的高度(mm)

图　5



图　6

图　7



图　8



图　9

电极厚度
0.1mm

1.0mm

0.7mm

0.8mm

12mm

8mm
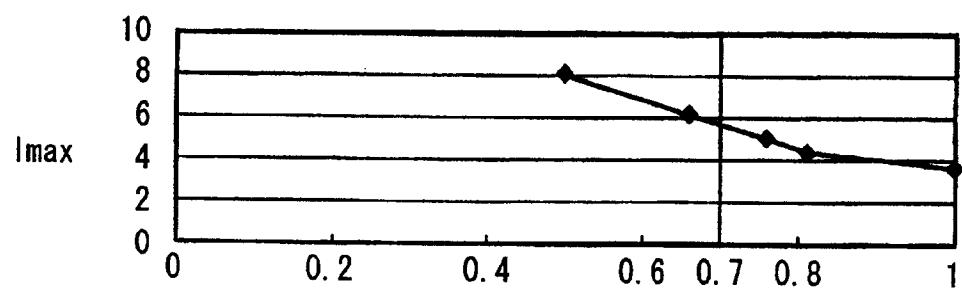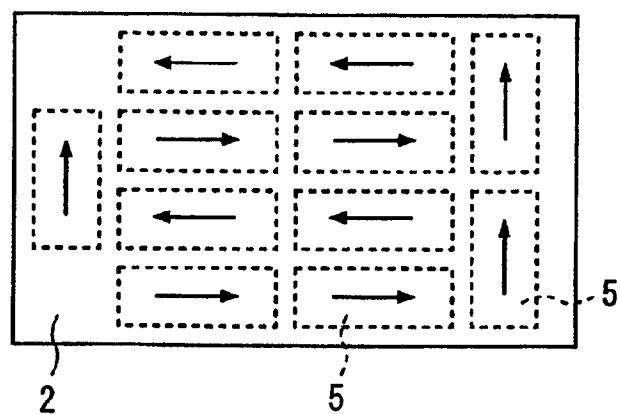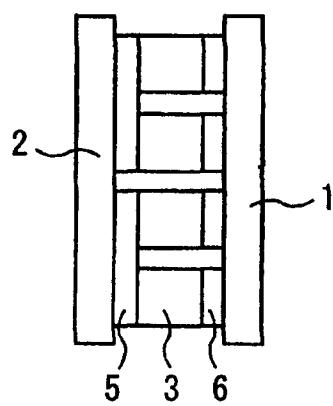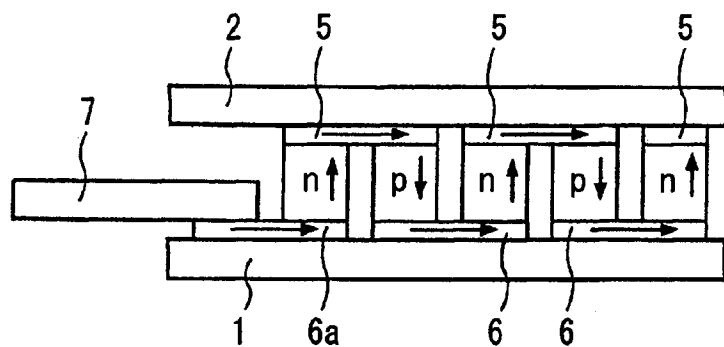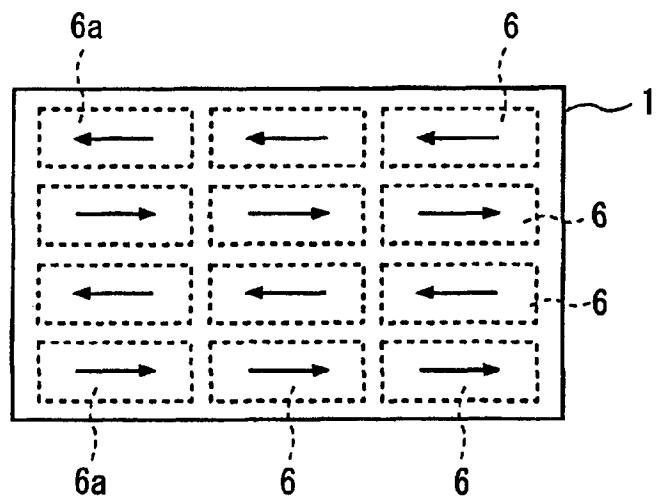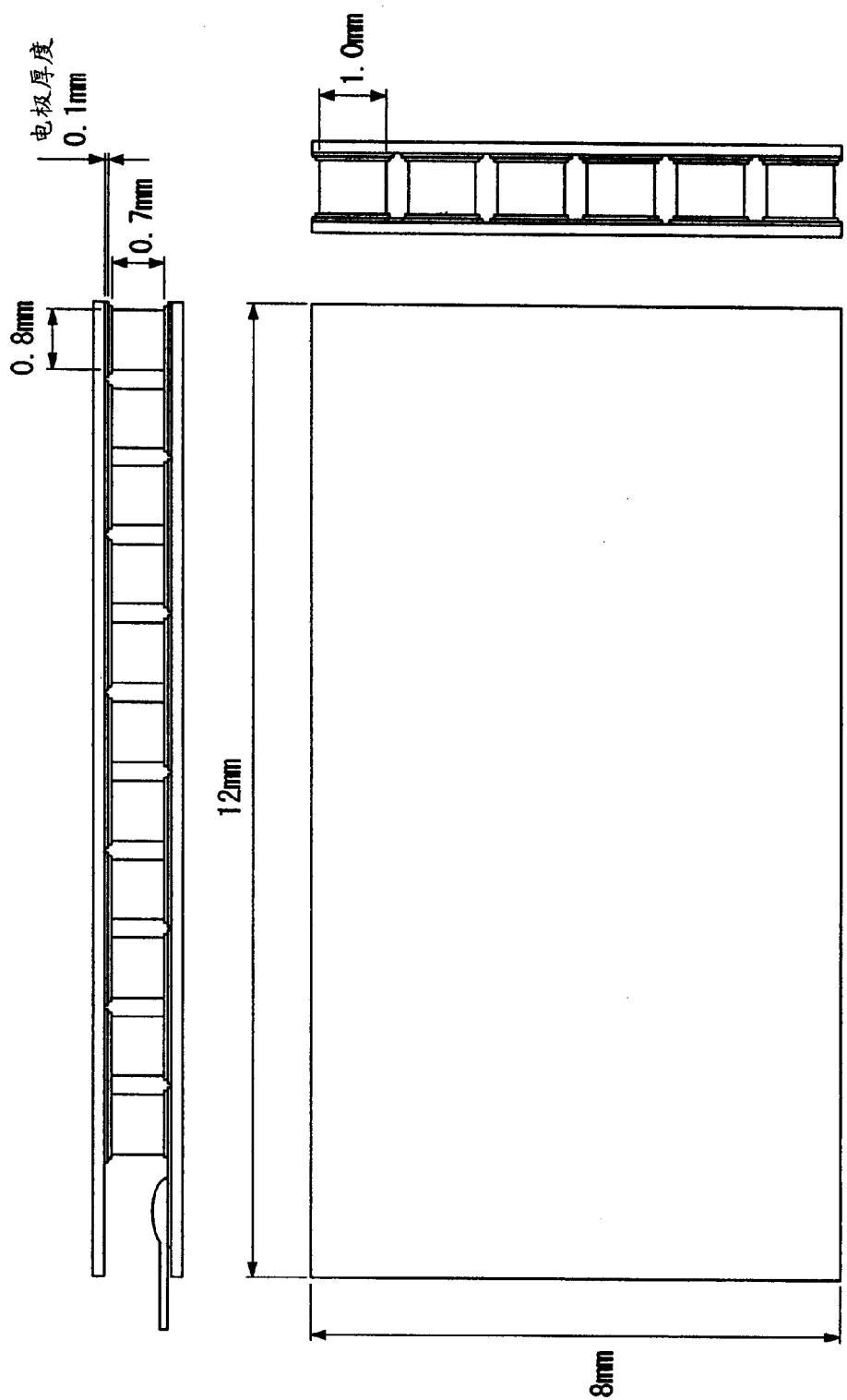
图 10
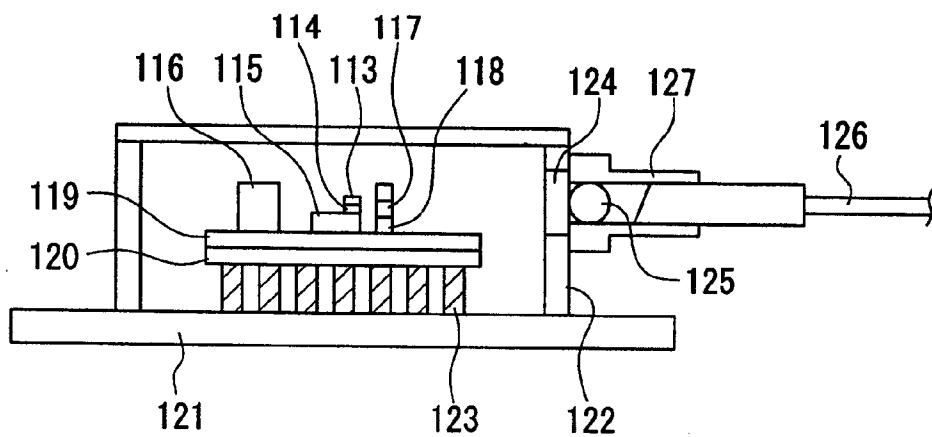
图 11

在激发激光器模块中的电流密度的效果



图 12